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ACID RAIN and RELATED AIR POLLUTANT DAMAGE

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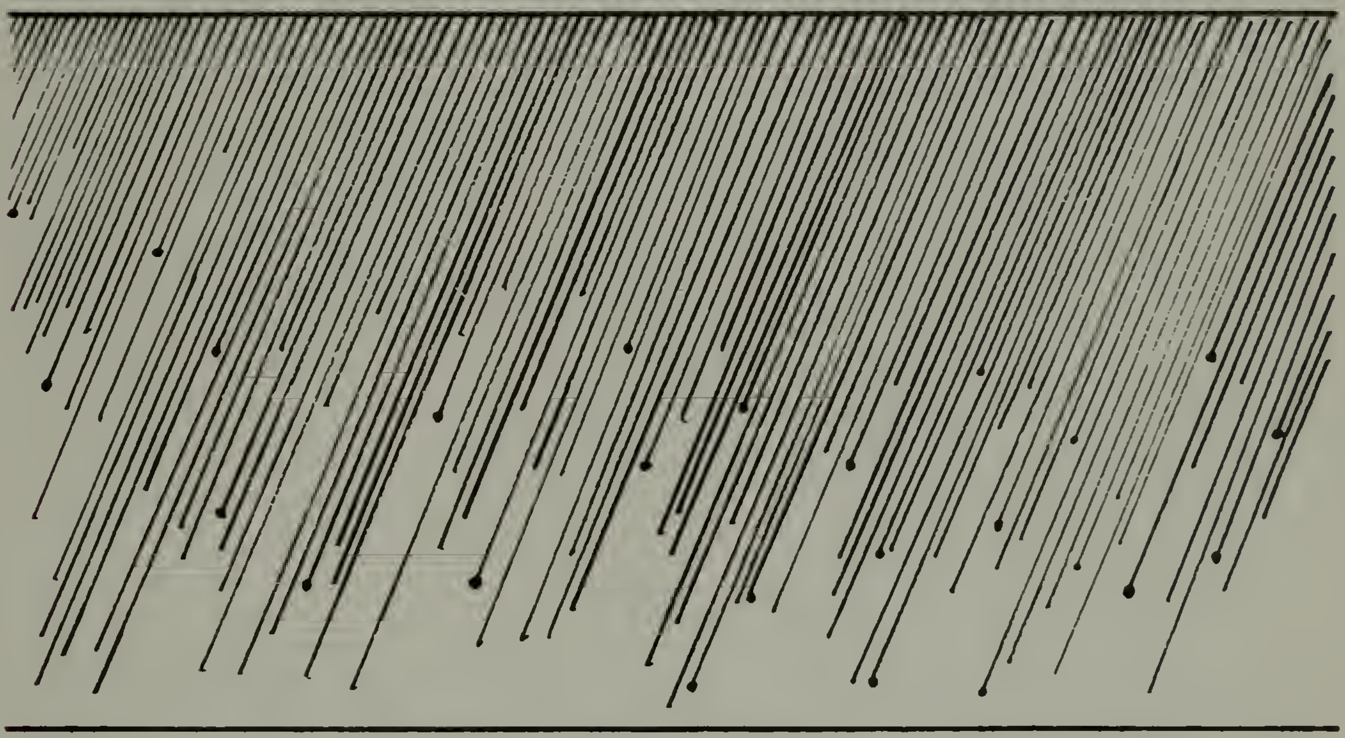
A NATIONAL and INTERNATIONAL CALL FOR ACTION



Commonwealth of Massachusetts

MICHAEL S. DUKAKIS
GOVERNOR

JOHN KERRY
LIEUTENANT GOVERNOR

JAMES S. HOYTE
SECRETARY OF
ENVIRONMENTAL AFFAIRS

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COMMISSIONER, DEQE

FORWARD

This Report makes an important contribution to our knowledge of the damages inflicted on the environment of the United States by acid rain. It also assists us in designing an effective solution to this problem by documenting the actions that have been taken by other industrialized nations. In sum, this Report makes a compelling case for the United States to undertake a major initiative to solve the acid rain problem.

I commend the environmental experts in the Department of Environmental Quality Engineering (DEQE) for the outstanding job they have done in compiling this excellent Report. In addition, Lt. Governor Kerry and Secretary of Environmental Affairs Hoyte have my grateful thanks for their leadership on this crucial environmental issue.

Finally, I want to personally thank Dr. Anthony Cortese, who until recently served as Commissioner of DEQE, for his extraordinary service to this Administration and to the citizens of the Commonwealth.

Governor Michael S. Dukakis

ABSTRACT

This study finds:

- Damage to natural and human-made resources from acid rain, or more accurately acid deposition, and other forms of air pollution is severe and is occuring throughout the world.
- A reduction in acid deposition and other pollutant emissions is the only way to alleviate the damages.
- The benefits from reducing acid deposition-related emissions are substantial and would accrue particularly to the midwestern states which would make the largest emission reductions.
- The United States, which is experiencing long range transport of acid deposition-related pollutants similar to European countries, should take its cue for action from these countries, as well as from Canada and Japan.
- The United States' program for air pollution and acid deposition control must be comprehensive. The damage is far more extensive geographically than the Northeast and the damages extend well beyond aquatic ecosystems.

This study recommends:

- Control of both SO_2 and NO_x -- both pollutants cause damages, so both should be reduced.
- A 48-state program -- effects are occurring throughout the continental United States, so the program must include all states with high emissions.
- Immediate commencement -- the damages are so great that waiting will only increase the clean-up efforts and the cost.
- Revision of the primary human health-based National Ambient Air Quality Standards.

I. EXECUTIVE SUMMARY

A. INTRODUCTION

Acid Rain and Related Air Pollutant Damage: A National and International Call for Action highlights the widespread environmental damages caused by acid rain (or more accurately, acid deposition) and related air pollutants in the United States and other countries, and discusses steps that other countries have taken to reduce air pollution and acid deposition. The purpose of the report is: 1) to provide information to decision makers to increase their awareness of the need for immediate action to reduce air pollution and acid deposition through discussion of damages throughout the United States, Canada, Japan, and Europe; and 2) to illustrate the feasibility of air pollution reductions in the United States by describing the actions taken in other countries.

Acid Rain and Related Air Pollutant Damage: A National and International Call for Action is the result of the Massachusetts Department of Environmental Quality Engineering (DEQE)'s efforts since early 1983 in researching the acid deposition problem on a local and national level and developing policies for acid deposition and related air pollutant control. This participation began with a proposal made by Massachusetts Governor Michael Dukakis in February, 1983, that a Massachusetts Acid Rain Strategy be formulated to accelerate research, make amendments to the Clean Air Act, and discuss with the federal government and the U.S. Environmental Protection Agency how to reduce emissions.

Governor Dukakis formed the Massachusetts Acid Rain Work Group (ARWG) co-chaired by Lt. Governor John Kerry and Secretary of the Executive Office of Environmental Affairs, James Hoyte in May, 1983, to assist in developing this strategy. The ARWG is comprised of representatives from DEQE and other state agencies, environmental groups, utility companies, labor, and industry. It advises the Governor and conducts technical and policy reviews on the acid rain issue. While consensus among the diverse interests represented on the ARWG is not always possible, the State's policies and positions have benefitted from an open discussion of alternatives. The concerns and issues raised by the ARWG have been taken to the Coalition of Northeast Governors, the National Governor's Association, and the New England Governors and Eastern Canadian Premiers Conferences to develop a national acid deposition control program that will address the concerns of the different regions of the United States.

To provide new information to the national acid rain debate, Lt. Governor John Kerry headed a Massachusetts delegation on a one-week fact-finding trip to Europe in January, 1984, to discuss acid deposition and air pollution damages and control programs with European nations actively involved in these issues. At that time, Lt. Governor Kerry requested that DEQE write a report that would promote a national acid deposition/air pollution control program and change the nature of the acid rain debate in three ways: 1) focus it on the effects of air pollution in general, and not just acid deposition--particularly human health impacts, materials damages, and visibility impairment, issues not usually discussed in relation to acid deposition; 2) widen it to include air pollution effects throughout the 48 states, and not just the widely-discussed effects on the New England and New York regions; and 3) direct it to the feasibility of solutions by showing what other countries have done to remedy acid deposition effects.

The first section of the report contains seven chapters on the effects of acid deposition and related air pollutants throughout the United States. The first chapter describes the pollutants, their concentrations, and where they occur. Following are chapters on aquatic resource damages, terrestrial resource damages, human health impacts, cultural resource and materials damages, and visibility impairment. The seventh chapter is an assessment of the economic benefits of acid deposition control.

The second section provides information on acid deposition and related air pollutant damages and air pollution control policies in other countries. Seven countries are discussed in the chapter entitled "Major Emphasis": Canada, West Germany, Great Britain, Japan, The Netherlands, Norway, and Sweden. These are countries whose governments either recognize that damage to resources is occurring from acid deposition and related air pollutants, and are acting to alleviate the damages; or are being prodded by other parties and organizations to do so. These seven countries have readily available information on this issue. The chapter entitled "Minor Emphasis" provides information on eight countries that have evidence of air pollution, but do not have readily available information on damages and/or do not have well developed control programs.

Finally, the Appendix explains the functions of the European and International Institutions that are active in acid rain issue, since these institutions may not be familiar to readers in the United States.

B. SUMMARY

Acid rain is frequently portrayed as air pollutants from midwestern coal-burning plants causing the death of fish in New England and New York state lakes. While accurate in part, this portrayal represents only a tiny part of the acid rain problem.

The phenomenon of acid rain encompasses a variety of pollutants other than the relatively high acidity (low pH) in rainfall. It includes all forms of precipitation, and acid in fog, dew, and mist. Additionally, the same pollutants that form acids in rain -- sulfur dioxide (SO_2), nitrogen oxides (NO_x), and their transformation products, sulfates and nitrates, -- can cause a plethora of problems in the ambient air and when dry deposited.

Acid rain, or more accurately acid deposition, and related air pollutants affect entire aquatic ecosystems. Increasingly, they are suspected as a major contributing factors in observed damage to terrestrial ecosystems. And, although often ignored, they also detrimentally affect human health, building materials and cultural resources, and visibility.

The effects of acid deposition and related air pollutants are widespread throughout the United States, and are not just in the Northeast (see Executive Summary Appendix for further detail). Recent research documents sensitive aquatic systems in areas from the Pacific Northwest to Florida. Growth declines in forests have been observed in the northern, central, and southern Appalachian Mountains, and as far south as North Carolina. Human health, visibility, and materials effects occur wherever air pollutants are found in significant concentrations. In fact, the ambient concentrations of these pollutants are generally highest in regions of highest emissions. Thus, the effects on materials, human health, and visibility are greatest in these areas, specifically the midwestern states.

Similar damages to natural and human-made resources are also occurring in Canada, Europe, and other parts of the world. Several countries have already begun taking steps to control the emissions that cause acid deposition, have made commitments to further reductions, and have joined with other countries to advocate international emission reductions.

Immediate action must be taken to reduce air pollution and acid deposition in the United States through emission reductions and revision of the National Ambient Air Quality Standards.

C. CONCLUSIONS

1. Damage to natural and human-made resources from acid deposition and other forms of air pollution is severe and is occurring throughout the world. Acid deposition is one significant symptom of air pollution problems involving primarily sulfur and nitrogen oxide emissions (SO_2 and NO_x) and resulting transported acids and acid particles. Acid deposition and other forms of air pollution are considered at least a contributing factor to the following effects:

   - Aquatic ecosystem damage caused by acid precipitation has been documented in Europe and eastern North America. Acidification of fresh water has occurred in New England and the greater Northeast, in southern Canada, and in other regions which lie downwind of or within major industrial areas. Aquatic resources which are sensitive to acid deposition also exist in the Southeast, areas of the central Rocky Mountains, and the Pacific Northwest. Continued current levels of acid deposition will likely lead to continued water resource acidification, loss of fish populations, and highly corrosive drinking water.

   - Growth declines in forests in the United States and forest damage in Europe are most likely caused by a combination of acid deposition, SO_2, NO_x, ozone, toxic trace metals, and environmental stresses such as drought. Declines in the United States have been documented in high elevation forests and in the Northeast, Ohio, and as far south as North Carolina. Perhaps most disturbing, the extensive decline in tree stands in low and high elevation regions of West Germany exhibited the same declines beginning in the 1960's that we are now seeing in the United States. In West Germany, as much as 35 percent of the forest area may be affected, up from eight percent in 1982 (Ministerium, 1983).

   - The air pollutants associated with acid deposition can have direct effects on human health. For example, evidence indicates that current SO_2 levels are likely to produce adverse health effects. Current short term peaks of nitrogen dioxide (NO_2) may increase respiratory illness rates and exacerbate

bronchoconstriction during asthmatic attacks Sulfates can cause bronchoconstriction at high concentrations. In addition, studies suggest that asthmatics and individuals with upper respiratory infections may be susceptible to nitrate-induced bronchoconstriction. The health effects of multiple pollutants acting together may be additive or synergistic. As a result, pollutant levels which have been judged safe when pollutants are in isolation may become hazardous when the pollutants occur simultaneously.

- Acid deposition and air pollution at current ambient levels is damaging materials -- metal, stone, and exterior coatings -- as well as important historic and cultural resources.

- The damage to human health and material resources is most severe where concentrations of pollutants are highest. Areas of high concentrations occur in many regions of the United States. Air pollution causes a deterioration in visibility. Such impairment is occurring throughout the eastern and southwestern United States. One study estimates that a 31-state 12-million ton SO_2 reduction will improve visibility in the eastern United States by over 13 percent (Latimer et.al., 1984).

2. Action to control air pollution must begin immediately.

   - The National Academy of Sciences (National Research Council, 1981) projects that, "At current rates of emissions of sulfur and nitrogen oxides, the number of affected lakes can be expected to more than double by 1990, and to include larger and deeper lakes."

   - It may already be too late to reverse the long-term decline of much of the central European forests from gaseous pollutants. The emission reductions that countries such as West Germany are undertaking may not save the forests, since the pollution effects appear to be cumulative and the recovery time long. Central Europe's experiences should

serve as a hard lesson for the United States; recent observations of forest decline in this country should be taken seriously.

- People with greatest risk to their health from exposure to air pollution include those with allergies, children, bronchitics, individuals with other severe respiratory and cardiovascular diseases, the elderly, smokers, and people who habitually breathe through their mouths. Continued risk to such a large proportion of our population must not be allowed.

- The historical and cultural resources being damaged are irreplaceable.

- Deterioration of visibility is affecting public enjoyment of scenic beauty.

3. A reduction in acid deposition and other related pollutant emissions is the only way to alleviate the damages.

   - Mitigation techniques do not exist for most of the effects described. According to the National Academy of Sciences (National Research Council, 1981), "Of the options presently available, only the control of emissions of sulfur and nitrogen oxides can significantly reduce the rate of deterioration of sensitive freshwater ecosystems." Where techniques do exist, such as lake liming and coating of metal statues, they can only realistically be applied to a limited number of the resources-at-risk.

4. The benefits from reducing acid deposition-related emissions are substantial and would accrue particularly to the midwestern states which would make the largest emission reductions.

   - In most estimates of the benefits of SO_2 reduction, benefits to aquatic resources account for less than 10 percent of the total benefits. The Midwest would receive a significant share of the total benefits from SO_2 control, since the damages for the other categories will be concentrated near those areas with the highest emissions, i.e., the Midwest.

- A 12-million ton SO_2 reduction program would result in a savings of approximately $2.3 billion annually in materials damage in the eastern United States.
- Latimer, et.al. (1984) estimated the value of visibility improvements from a 12-million ton SO_2 reduction to be approximately $4.2 billion annually. The states with the highest emissions would have the greatest improvements in visibility.
- The Latimer study indicated that the reduction program would reduce human exposures to sulfate in 1995 by 36 percent.

Unfortunately, given the current level of understanding, the total benefits from different levels of control cannot be compared with control costs, since it is impossible to estimate the cost of damages from acid deposition to some resources, and hence quantify the benefits. Based on the best available information, however, the benefits of acid deposition controls (12-million ton emission reduction) far outweigh the costs. Benefits to visibility and materials alone (estimated at $6.5 billion annually) approximately equal cost of control estimates. If health, terrestrial, and aquatic benefits are included, the total benefits far outweigh the cost of control.

5. The United States, which is experiencing long range transport of acid deposition-related pollutants similar to European countries, should take its cue for action from these countries, as well as from Canada and Japan. The threat of environmental damage within their own borders has caused a number of European countries to reduce their emissions and to urge other countries whose emissions affect them to make similar reductions. The existence of long range transport is no longer questioned in Europe and Canada. The only questions are: How much should emissions be reduced, and where?

- The Scandinavians were the first to recognize the dangers of acid deposition, and the first to press for international action. Sweden, with its poorly buffered solid and relatively high acidic deposition, estimates that 18,000 of its approximately 85,000 lakes are showing signs of acidification. Sweden is also very concerned with acidification of its municipal water supplies. To combat acidification damage, Sweden has reduced its SO_2 emissions by 35 percent since 1970. It is also one of the stongest advocates for a 30 percent reduction of SO_2 emissions for all European countries.

- In Norway, massive damage to aquatic resources has also promoted local action and calls for international action. The combination of poorly buffered terrain, heavy snowfalls resulting in spring acid surges, and acid deposition (pH 4.2 to 4.5) have resulted in extinction of fish populations in 1,750 of 5,000 lakes in southern Norway. The Norwegians focus on international action because over 90 percent of acid deposition in Norway originates from areas outside Norway's borders. Nevertheless, the Norwegians plan to reduce their SO_2 emissions by 30 percent by 1993. They have already instituted a low sulfur fuel regulation.

- The Netherlands also attributes a large portion of its acid deposition to sources outside its borders. Terrestial damage from acid deposition and related air pollution worries the Dutch, as their forests are exhibiting symptoms similar to the damaged forests in West Germany. The Dutch are also acutely aware of damage to their cultural resources. Millions of dollars have been spent to restore monuments, carillons, and stained glass windows. Similar types of materials damage are common to many historic structures throughout Europe.

- Action in Europe has been recently galvanized by West Germany. Over a very short time, the damage occurring to West Germany's forests caused the government to reverse its position from opposing pollution controls to strongly advocating at least a 30 percent reduction in air pollutants across Europe. The West German government has also established a program to unilaterally reduce SO_2 emissions by 30 percent, and to institute United States automobile emission control standards for NO_x and hydrocarbons.

- Canada, with its heavy economic emphasis on timber industries and tourism, places environmental concerns high on its list of national priorities. Damage occurring to Canadian aquatic resources and the threat of forest damage similar to West Germany has lead to a commitment to a 25 percent reduction in SO_2 emissions by 1990. An additional 25 percent reduction is promised if the United States passes legislation requiring a 50 percent reduction of SO_2 emissions. Over 48,000 lakes in Canada are threatened by acidification. Canada is also in the forefront of international efforts to control air pollution.

The United States' continued reluctance to undertake emission reductions has disappointed and strained relations with Canada and European countries that have come to view the United States as a world leader on environmental issues since the 1970's. A number of countries such as Sweden and the Netherlands are enforcing strict industrial and utility emission standards, conserving energy, and/or examining new ways to provide energy for businesses that will not contribute to acid deposition and air pollution. It is in the United States' best interests to learn from other countries experiences and proceed with the job of lowering our deposition levels before massive damage is visible.

6. The United States' program for air pollution and acid deposition control must be comprehensive. The damage is far more extensive spatially than merely the Northeast. The resources being damaged include health, materials, forests, and visibility as well as aquatic ecosystems. Thus our response must not be piecemeal, e.g., treating a few symptoms through lake liming.

RECOMMENDATIONS

(1) An emission reduction program as follows:

- (a) Control of both SO_2 and NO_x -- both pollutants cause damages, so both should be reduced.
- (b) A 48-state program -- effects are occurring throughout the continental United States, so the program must include all states with high emissions.
- (c) A control program which will protect virtually all sensitive resources. Additional actions to protect highly sensitive resources may be required.
- (d) Immediate commencement -- the damages are so great that waiting will only increase the cleanup efforts and the cost.

(2) Revision of the primary human health-based National Ambient Air Quality Standards consisting of promulgation of:

- (a) A fine particulate standard -- the present total suspended particulate (TSP) standard is inappropriate because it fails to directly regulate the most health damaging particulate fraction. Establishment of a standard for fine particles would also limit human exposure to many organic and metallic compounds associated with these particles which are derived from common sources.
- (b) A one-hour SO_2 standard -- the present SO_2 daily and annual standards allow short-term SO_2 peaks which may adversely affect high risk groups.
- (c) A one-hour NO_2 standard -- the present NO_2 annual standard similarly allows for peak concentrations which may adversely affect high risk groups.

The implementation of both of these recommendations will provide a comprehensive approach to the acid deposition problem. It will protect all the resources at risk, both those damaged by acid deposition and those damaged by ambient air concentrations of the related pollutants.

EXECUTIVE SUMMARY APPENDIX

AREAS IN THE UNITED STATES OF POTENTIAL DAMAGE DUE TO ACID DEPOSITION AND RELATED POLLUTANTS

Documented damage to resources due to acid deposition and related air pollutants has already occurred in several areas of the United States. Furthermore, although not yet documented, damage may be occurring in many additional areas. To demonstrate the widespread nature of the risk of damage, the following series of maps indicates areas where damage due to acid deposition and air pollution is occurring or may be occurring in the United States.

Threshold pollutant levels, i.e., levels below which damage has not been documented, have been suggested only for moderately sensitive aquatic resources and for only some of the pollutants and averaging times that affect human health. National Ambient Air Quality Standards to protect human health have been promulgated for four pollutants related to acid deposition: SO_2, NO_2, TSP, and ozone. However, there are no standards for sulfates, nitrates, or fine particles. In addition there are no short term standards for SO_2 and NO_2. For materials, visibility, terrestrial ecosystems, and certain human health effects, it is not possible at this time to state a threshold level. In addition, because extensive survey research has not been conducted even on aquatic resources and health impacts, it is not possible to document that damage has occurred in all these areas. Therefore, the maps indicate where concentrations of pollutants occur and where sensitive resources are located. These are the areas where damage is most likely.

Very few nationwide maps of pollutant levels have been developed. The ones used here are based on readily available information. In some cases, it was necessary to use maps displaying data from the mid 1970's since they were the most current. In addition, maps were not available for all pollutants, for all the appropriate averaging times, and for all 48 states to illustrate each effect. In particular, no nationwide maps indicating NO_2 concentrations or particles were available. NO_2 affects human health; particles affect both health and materials. Finally, all maps presented in this section were generalized from the original sources for ease of presentation and to increase readability. For pollutants which have National Ambient Air Quality Standards, the reader is also referred to the maps of nonattainment areas

in Section II of the report. All such areas have the potential for adverse effects.

Areas of potential aquatic damage are shown in Fig. I-1. The dotted areas represent general locations of low alkalinity in surface waters. These waters are sensitive to acid deposition. Isopleths indicate lines of approximately equal pH of wet deposition in 1982. The National Academy of Sciences (National Research Council, 1981) reports that precipitation with a pH lower than 4.6 to 4.7 may lead to degradation of sensitive freshwater ecosystems. Thus, dotted areas within the 4.6 pH line are areas of potential damage. Such areas are located in all regions east of the Mississippi River except the Gulf states.

Fig. I-2 shows the potential of soils and bedrock in the eastern United States to reduce acidity from atmospheric deposition (sulfate) in 1980. Patterns indicate low, moderate, or high potential to reduce the acidity of acid deposition. Agricultural and urban areas are blank and have a high potential since management and land use practices (liming, fertilizing, etc.) in these areas would tend to dominate modification of acid deposition. According to Olson et. al. (1982), a low potential implies that acid deposition would be transferred to aquatic systems as acid. High potential areas would generally be able to reduce acidity so that impacts to aquatic systems would be minimal. Moderate potential would be between the extremes in reducing acidity, and also may be more variable: a moderate county may have both low and high potential areas. Fig. I-2 also shows sulfate deposition. Several areas of low potential to reduce acidity are also receiving high sulfate deposition. These include parts of New England, New York, the Appalachians, and the South.

The next three figures show areas of potential damage to forests from acid deposition and air pollution. Causes and effects on forest systems are complex and poorly understood. Therefore, these maps should be interpreted with caution. Suspected causes of potential damage in the United States include ozone, sulfate deposition, low pH precipitation, trace metals, such as lead and/or a combination of these pollutants.

In Fig. I-3, isopleths represent lines of approximately equal pH of wet deposition in 1982. Although it is not possible to state what level of pH will lead to degradation on forest systems, low pH areas have the potential for damage. Similarly in Fig. I-4, isopleths show sulfate deposition. Again, a threshold level for sulfate in terrestrial ecosystems has not been determined (particularly because sulfate is accumulating in soils).

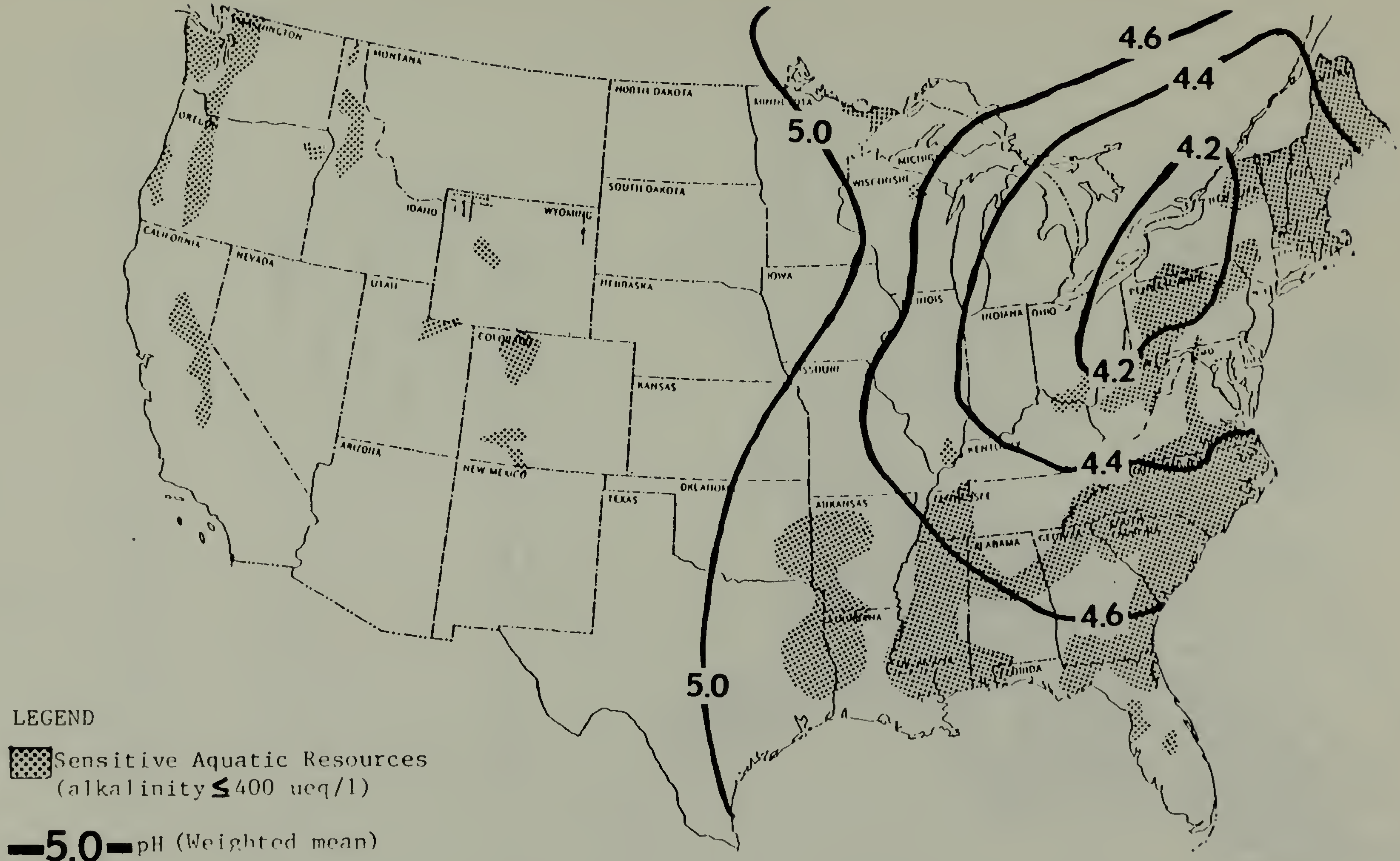
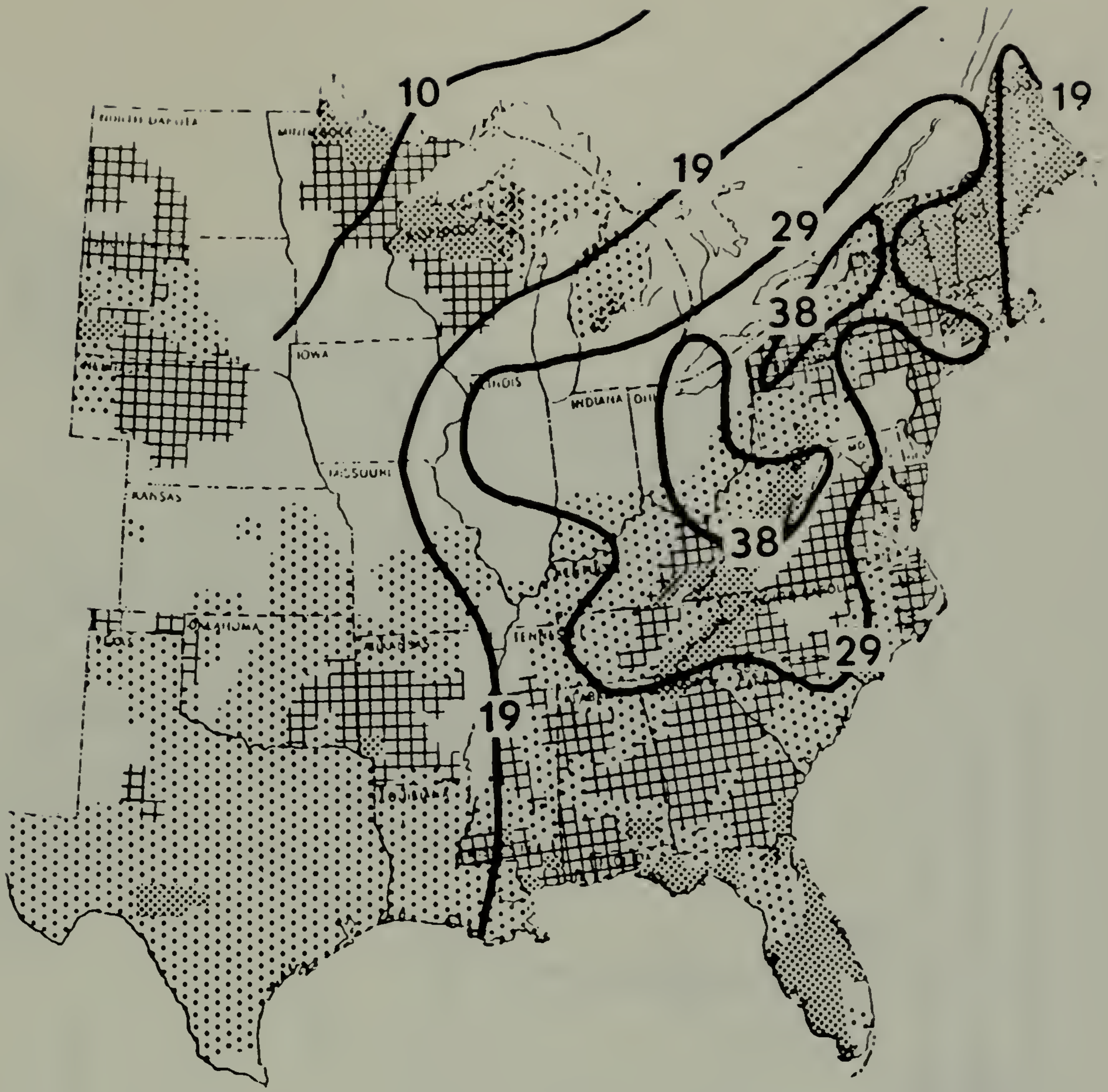


Fig. I-1 Regions of potential damage to sensitive aquatic resources (alkalinity ≤ 400 ueq/1) due to low pH levels of wet deposition (1982). (Adapted from Omernick, 1983; NAPAP, 1984)



LEGEND

Potential of Soils and Bedrock
to Reduce Acidity of Atmospheric Deposition

▒ low potential

▦ moderate potential

⁘ high potential - natural

☐ high potential - agricultural and urban areas

—29— Sulfate Deposition in Kilograms per Hectare

Fig. I-2 Potential of soils and bedrock to reduce acidity from atmospheric deposition (wet sulfate deposition kg/ha) (1980) in the eastern United States. (Adapted from Olson, et. al., 1982; U.S.-Canada MOI, 1983)

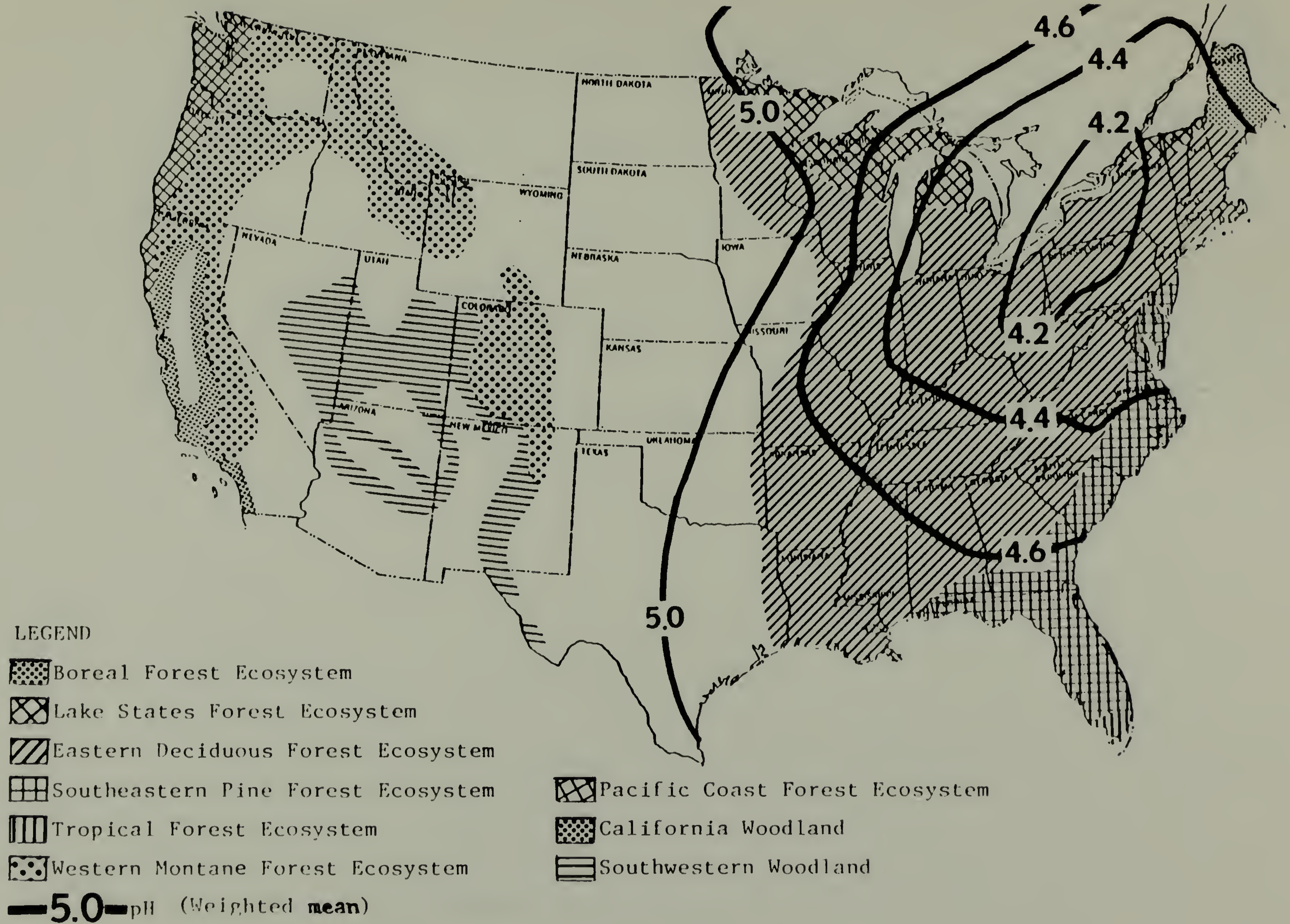
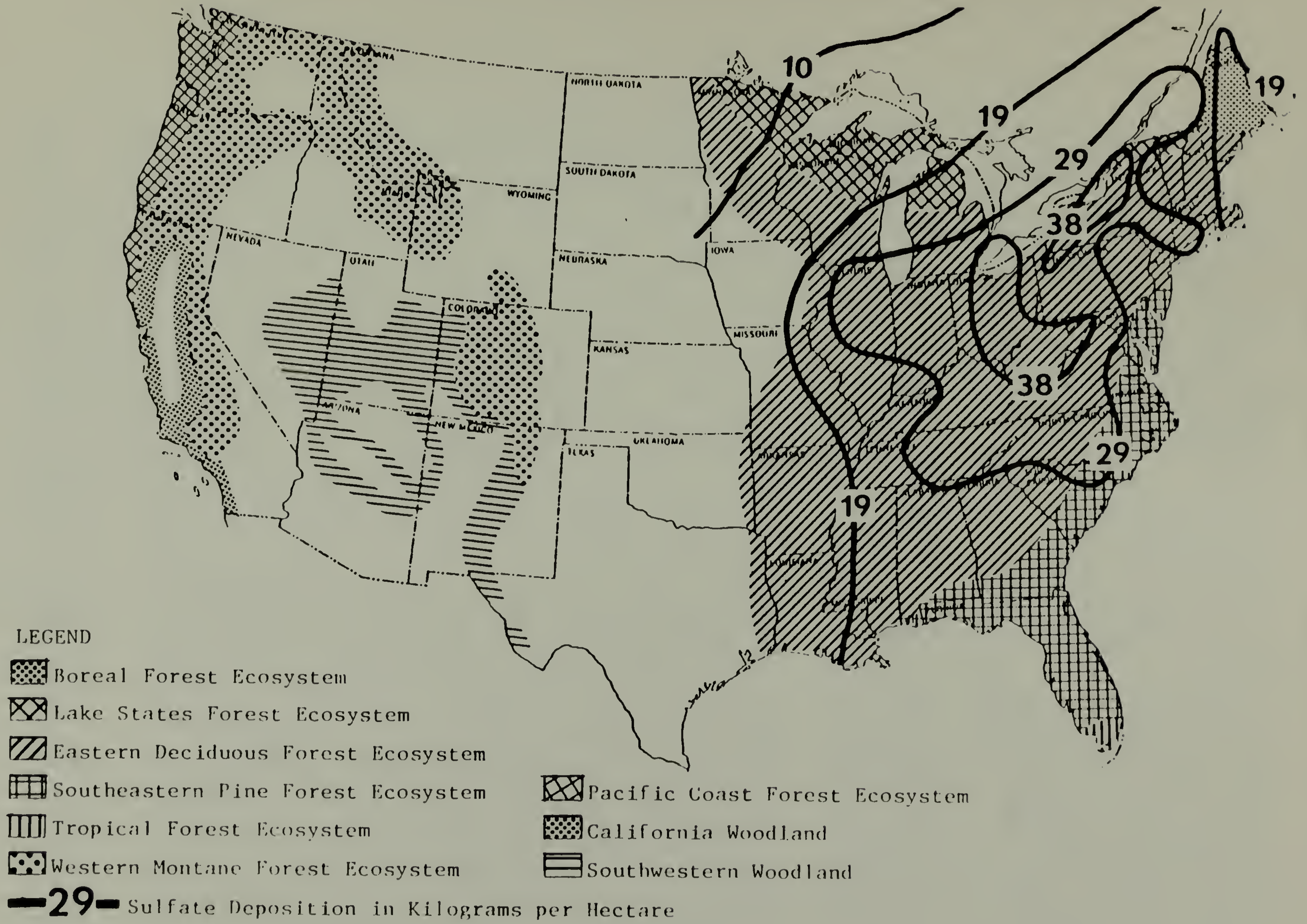


Fig. I-3 Regions of potential damage to forests due to low pH levels of wet deposition (1982). (Adapted from McLaughlin et. al., 1982; NAPAP, 1984)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19
29
38
38
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19
19
MONTANA
NORTH DAKOTA
SOUTH DAKOTA
WYOMING
NEVADA
UTAH
NEBRASKA
IOWA
COLORADO
KANSAS
MISSOURI
ARIZONA
NEW MEXICO
OKLAHOMA
TEXAS
LEGEND
Boreal Forest Ecosystem
Lake States Forest Ecosystem
Eastern Deciduous Forest Ecosystem
Southeastern Pine Forest Ecosystem
Tropical Forest Ecosystem
Western Montane Forest Ecosystem
Pacific Coast Forest Ecosystem
California Woodland
Southwestern Woodland
29 Sulfate Deposition in Kilograms per Hectare

Fig. I-4 Regions of potential damage to forests due to high sulfate deposition in precipitation (kg/ha) (1980). (Adapted from McLaughlin et. al., 1982; U.S. - Canada MOI, 1983)

Elevated sulfate levels east of the Mississippi River, however, suggest potential for damage.

Fig. I-5 presents daytime ozone concentrations for the 1978 growing season. Highest monitored concentrations in forested areas were found from Virginia to Georgia, in Mississippi, Arkansas, Missouri, and Illinois, and in southern California. The next highest levels were scattered around the country and covered large areas of the South and the Southwest. Ozone damage to both crops and forests has been documented. In fact, ozone is the long range transported pollutant that most affects vegetation (US-Canada MOI, 1983). This figure indicates that large areas of the United States may have the potential for forest damage due to ozone.

Ozone and sulfate, along with SO_2, NO_x, metals, and nitrates are rarely present alone, and may act on forest systems in combination, with one pollutant intensifying the effect of another. Thus, the areas where high concentrations of two or more pollutants occur may be especially susceptible to damage.

Areas of potential human health impact and materials damage caused by ambient pollutants are indicated in the next series of figures. The patterns in the figures show population density in 1980. Fig. I-6 presents yearly average ambient sulfate concentration during the mid 1970's. Most of the data on health effects of sulfate were developed for healthy individuals, and current sulfate levels are far below the levels at which adverse effects were observed in the studies. However, high risk groups, such as asthmatics and other individuals with chronic respiratory diseases, react adversely to far lower levels. In addition, the role of simultaneous exposure to sulfates and other respiratory irritants and toxins cannot be underestimated. Thus, this figure indicates the large number of people who are exposed to elevated sulfate levels (>10 ug/m^3) which may be particularly harmful to the high risk groups. Fig. I-6 also illustrates areas of potential increased materials damage. In this case, population density is assumed to represent density of material resources. Based on this map, the greatest impact to human health and material resources is expected to be occurring in the Ohio River Valley region, followed by the rest of the eastern United States except the most northeasterly and southeasterly corners. The Los Angeles area, although not included in this figure, also has elevated sulfate levels.

Fig. I-7 shows population density and one-hour SO_2 levels in non-urban areas in the eastern United States from August, 1977 to July, 1978 to illustrate potential

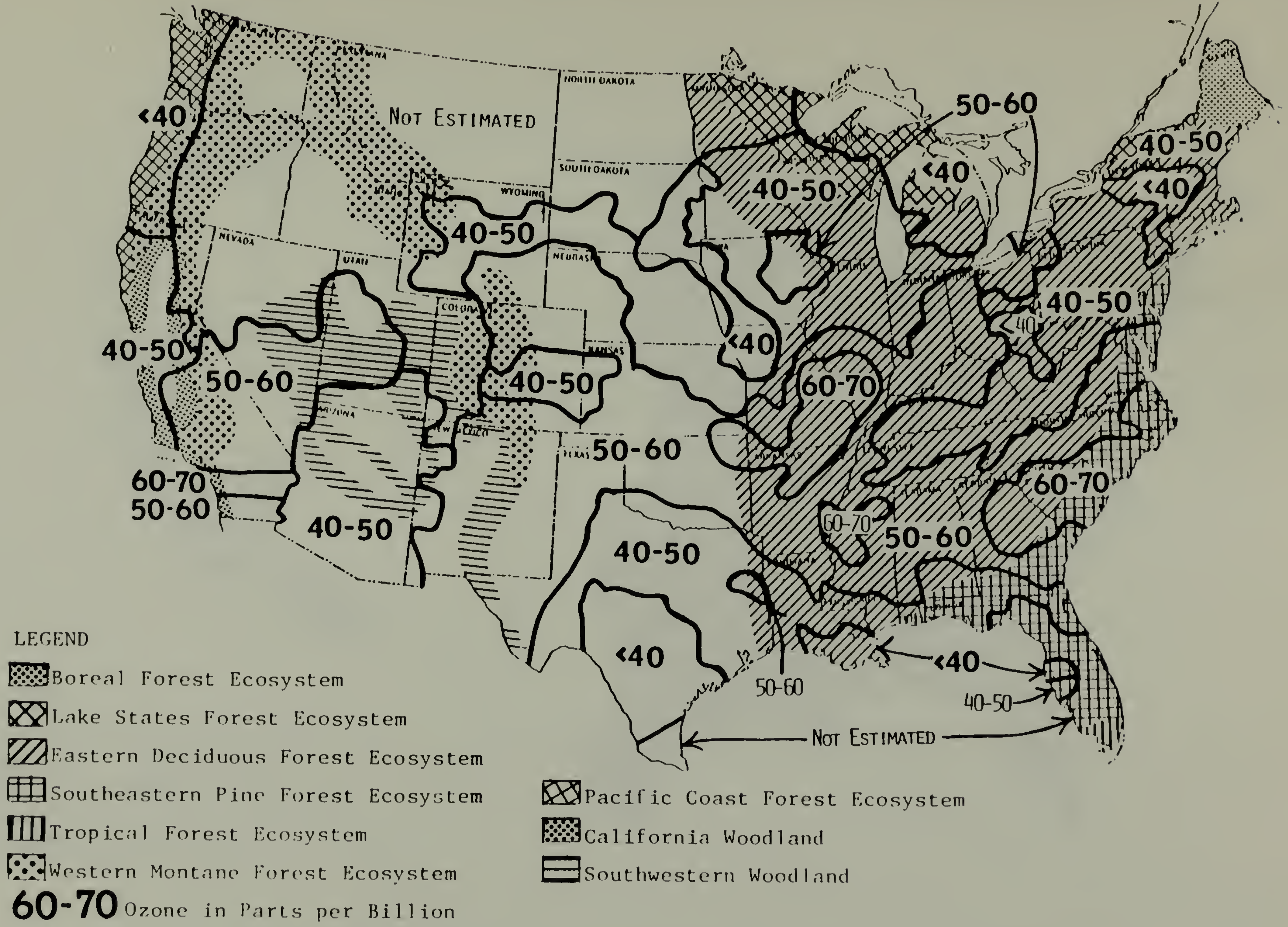


Fig. I-5 Regions of potential damage to forests due to high ozone levels (ppb; daily seven-hour average) (June-September average, 1978). (Adapted from McLaughlin, et.al., 1982; Office of Technology Assessment, 1984)

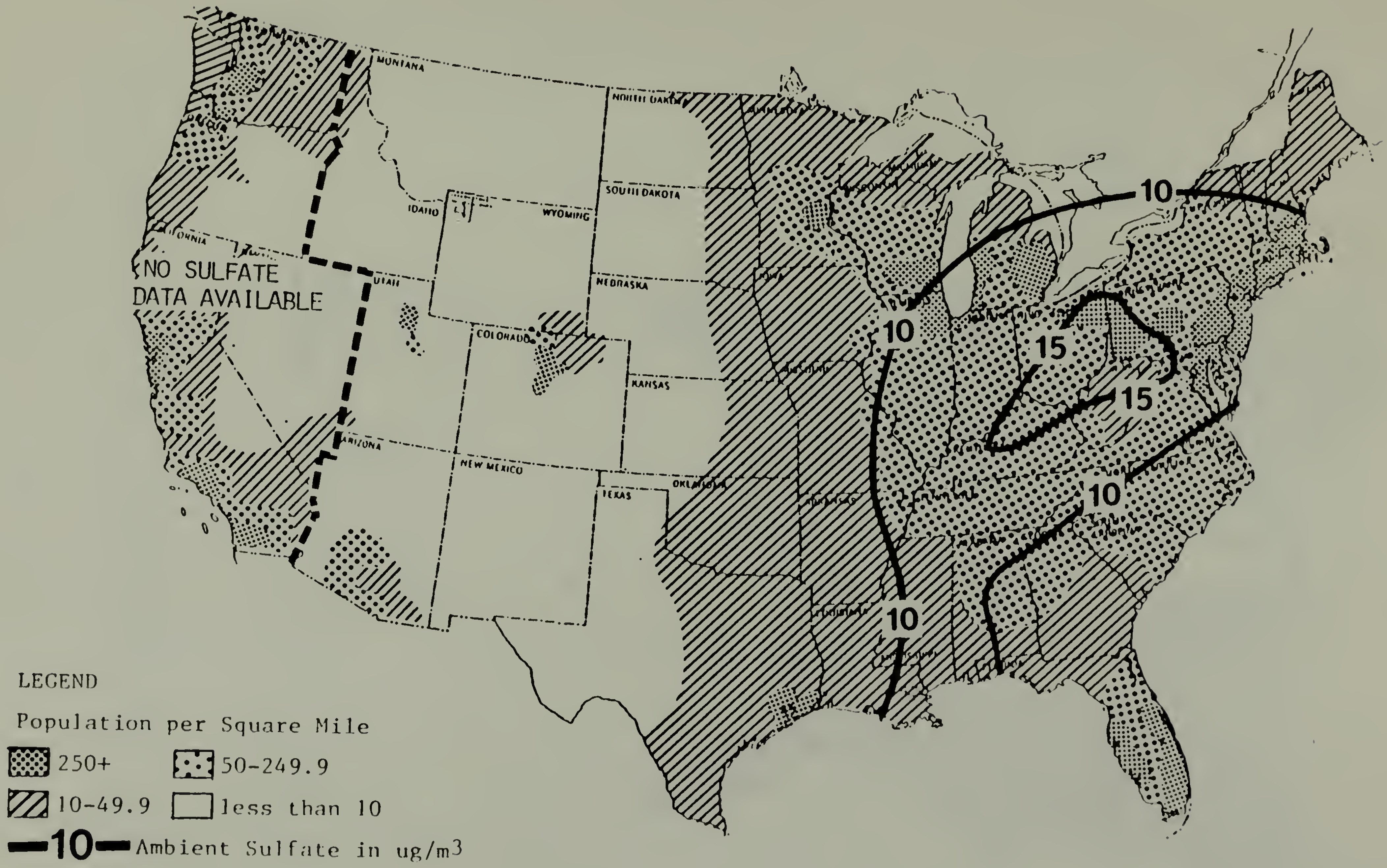
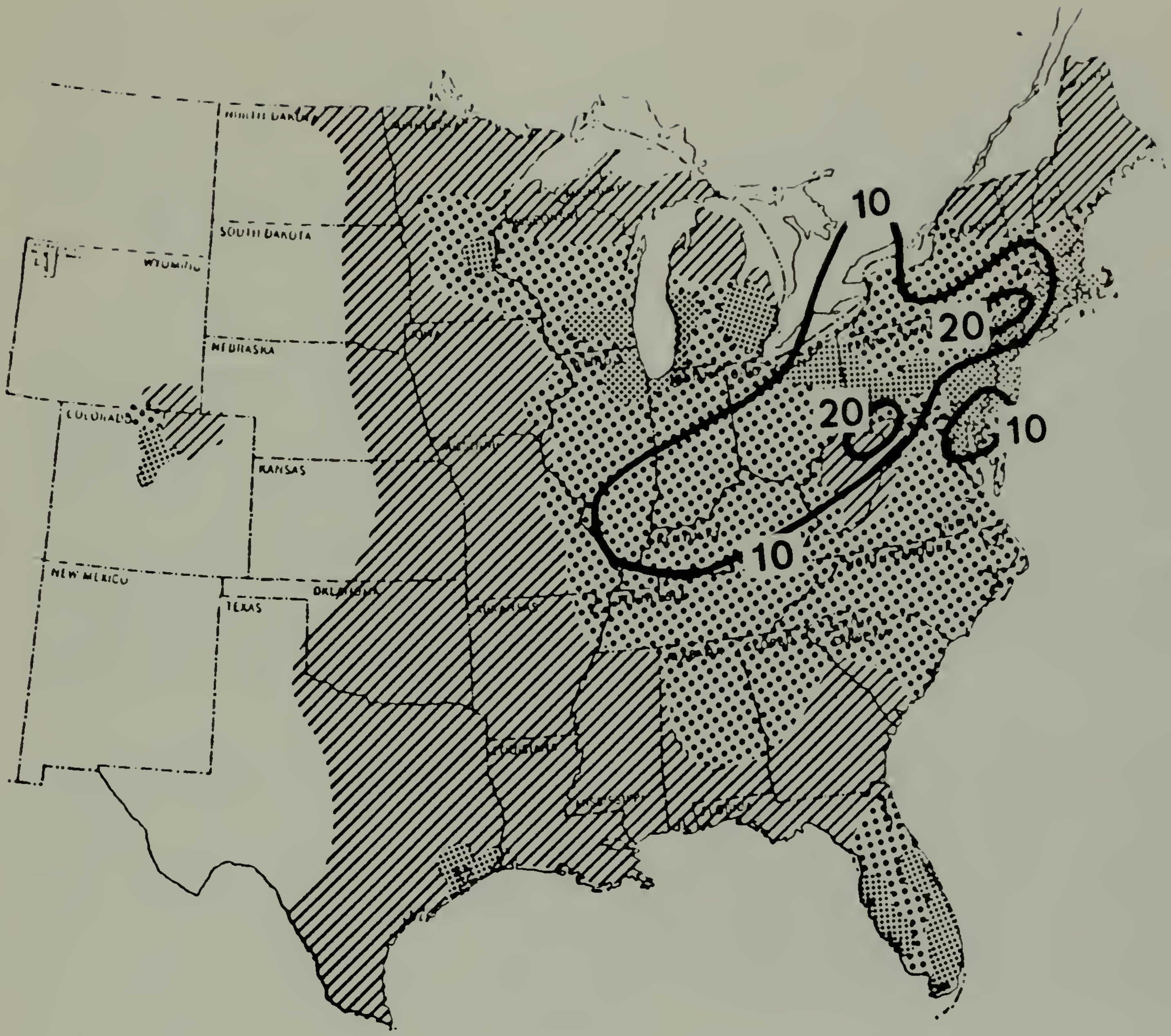


Fig. I-6 Regions of potential health and materials impacts due to high levels of ambient sulfate (ug/m^3; yearly average) during the mid 1970's. (Adapted from U.S. Bureau of Census, 1980; Wilson et. al., 1980)



LEGEND

Population per Square Mile

▩ 250+ ⠿ 50-249.9

▨ 10-49.9 ☐ less than 10

—20— Sulfur Dioxide in Parts per Billion

Fig. I-7 Regions of potential materials damage due to high sulfur dioxide concentrations (ppb; one-hour average) (August 1977-July 1978). (Adapted from U.S. Bureau of Census, 1980; U.S. EPA, 1983)

damage to materials. While these levels have not been found to affect human health, material resources may be affected. Furthermore, in urban areas, peak SO_2 concentrations are higher. Evidence indicates that current levels of SO_2, particularly when SO_2 is combined with fine particles, are likely to produce adverse health effects. (No map was readily available to illustrate one-hour urban concentrations or levels in the western United States.)

In Fig. I-8, population density and ambient annual nitrate levels in urban areas are shown. Nitrates may pose a significant human health risk in several ways. Inhalation of nitrate particles may particularly threaten individuals with severe asthma or upper respiratory infections. Nitric acid vapors are very potent irritants to the respiratory system. Little is known, however, about nitric acid gas toxicity at ambient air concentrations. Likewise, no threshold for effects has been suggested for nitrate particles. Greatest concentrations, however, are found in some of the most densely populated areas of the northeastern United States.

Fig. I-9 relates population density to daily ozone concentrations from July to September, 1980. Ozone by itself has well-known adverse health effects. In addition, studies have shown that ozone in combination with SO_2 causes increased bronchoconstriction. Unfortunately, no map showing one-hour peak concentrations was readily available to illustrate potential human health effects. However, Fig. I-9 does illustrate general locations of high ozone levels.

The last map (Fig. I-10) indicates areas of potential visual impairment due to high ambient sulfate levels during the mid 1970's. Patterns indicate miles of visual range, while isopleths show yearly average sulfate concentrations. The area of highest sulfate levels corresponds to an area of low visual range: the Ohio River Valley region.

Fig. I-10 also shows Class I Federal areas. The Clean Air Act as amended August 1977 declares that visibility protection is a national goal for these areas, which generally consist of international parks, national wilderness areas, and national memorial parks which exceed 5,000 acres, and national parks which exceed 6,000 acres.

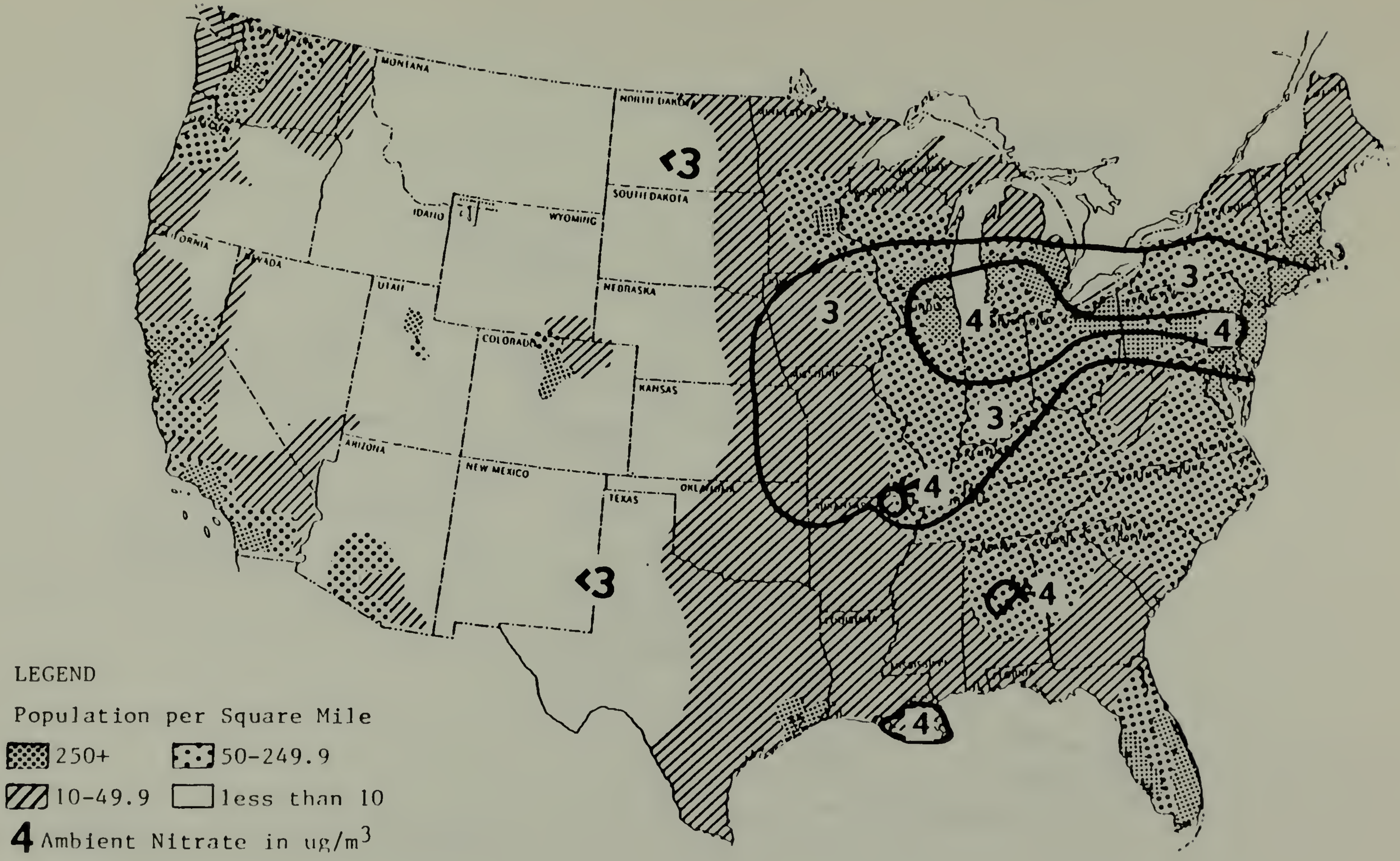


Fig. I-8 Regions of potential health impacts due to high mean annual urban ambient nitrate levels (ug/m^3). (Adapted from Bureau of Census, 1980; Akland, 1977)

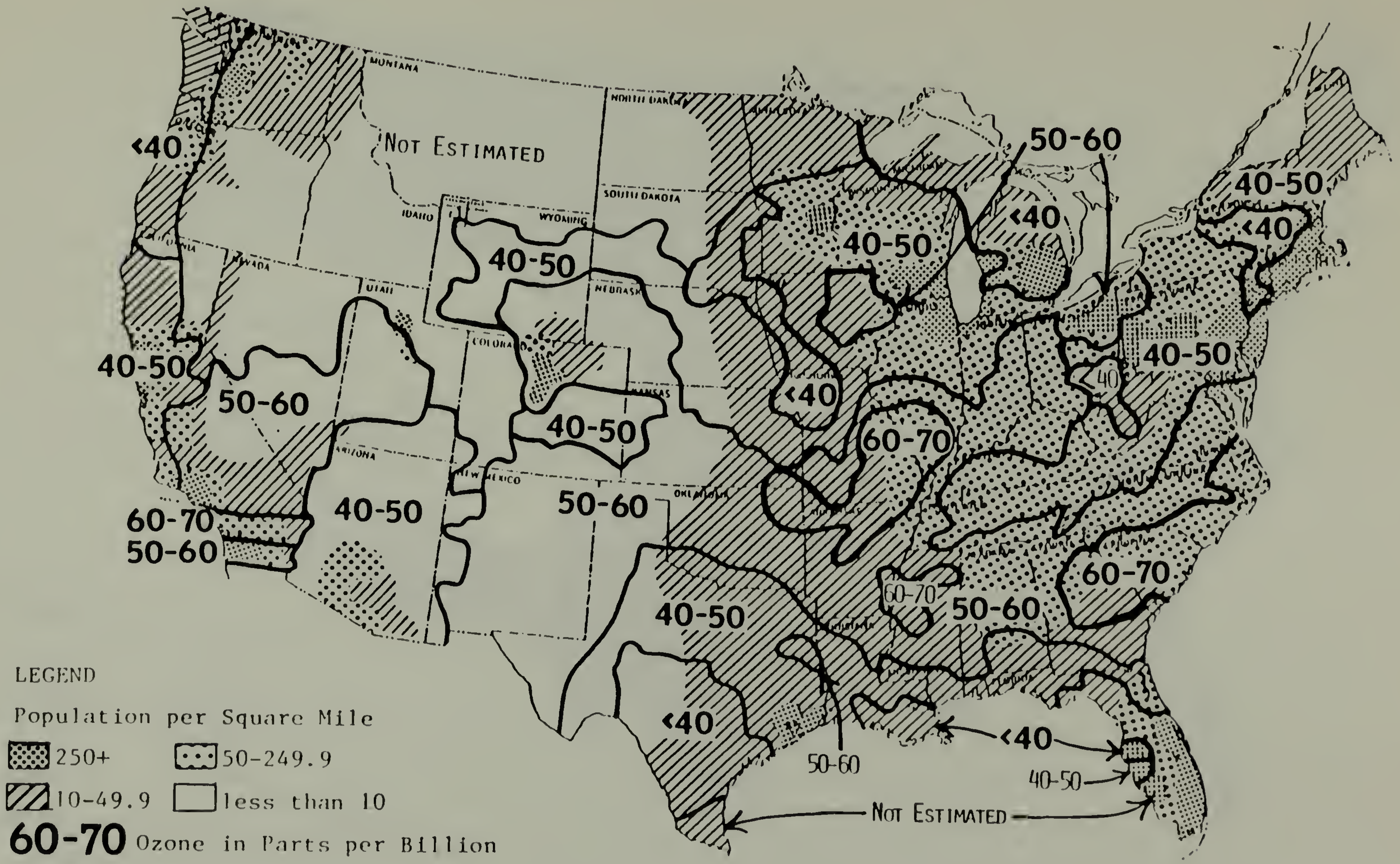


Fig. I-9 Regions of potential health impacts due to high ozone levels (ppb; daily seven-hour average) (June-September average, 1978). Adapted from Bureau of Census, 1980; Office of Technology Assessment, 1984)

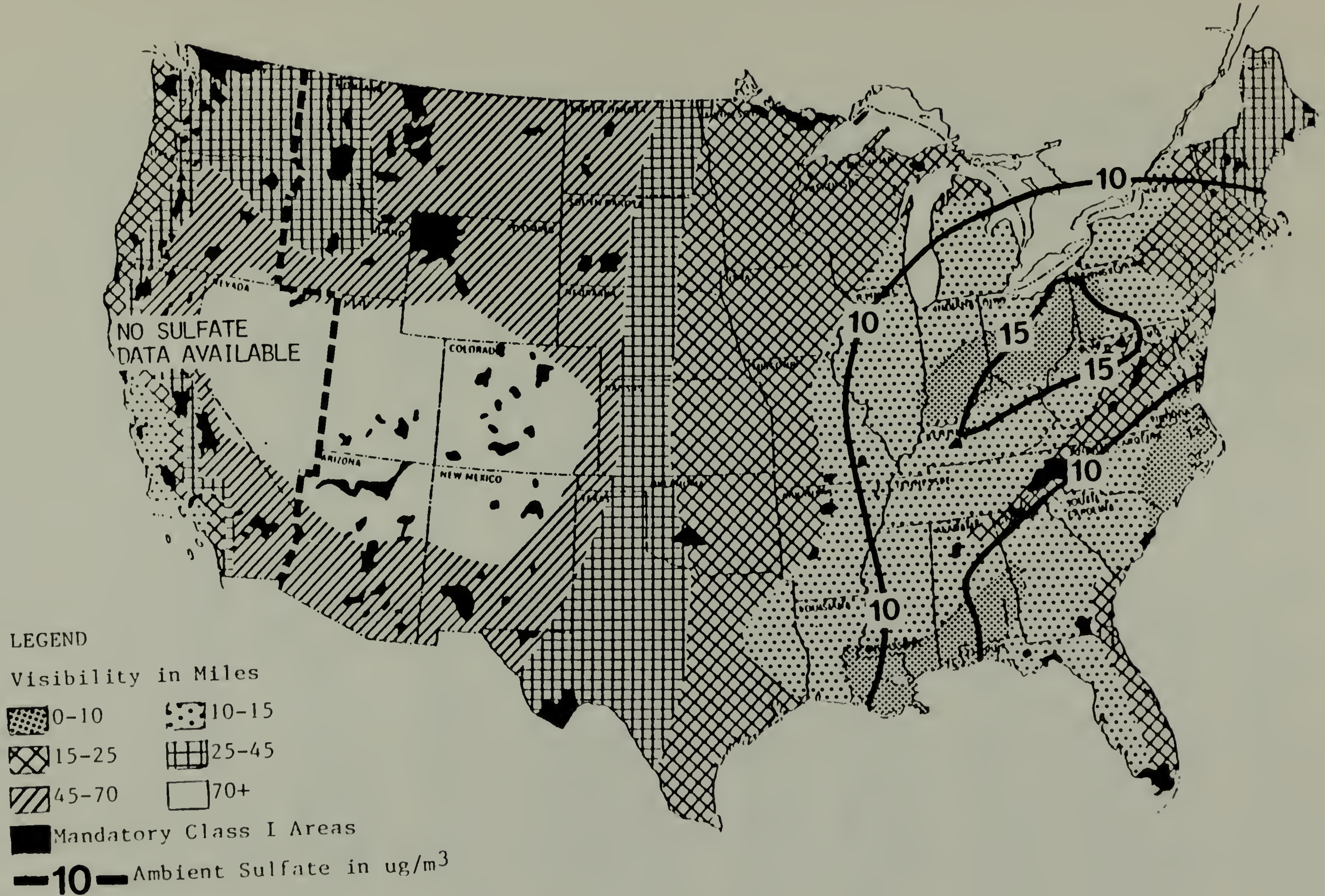


Fig. I-10 Regions of potential visual impairment due to high ambient sulfate levels (ug/m^3 yearly average) during the mid 1970's. (Adapted from U.S. EPA, 1979; Wilson et. al., 1980)

REFERENCES

Akland, G.G. 1977. Air quality data for nonmetallic inorganic ions 1971 through 1974 from the National Air Surveillance Network. U.S. Environmental Protection Agency. EPA-600/4-77-0003. As cited in USEPA, 1982.

Latimer, D.A., E. Anderson, H. Hogo, R.G. Dreson, R.E. Morris, and P. Saxena. 1984. Visibility and other air quality benefits of sulfur dioxide emission controls in the eastern United States (I): Systems Applications, Inc. San Rafael, CA. For U.S. Environmental Protection Agency, Office of Policy Analysis. Washington, D.C.

Ministerium fur Ernahrung, Landwirtschaft, Umwelt and Forsten, Baden-Wurttemburg. 1983. The dying off of the forest.

McLaughlin, S.B., T.J. Blasting, and D.C. West. 1982. Forest systems of the United States and areas of maximum frequency of air stagnation episodes. Oak Ridge National Laboratory, Oak Ridge, TN.

National Acid Precipitation Assessment Program (NAPAP). 1984. Annual Report 1983 to the President and Congress. EOP Publications. Washington, D.C.

National Research Council. 1981. Atmosphere-biosphere interactions: Toward a better understanding of the ecological consequences of fossil fuel combustion. A report prepared by the Committee on the Atmosphere and the Biosphere, Board on Agriculture and Renewable Resources, Commission on Natural Resources. Washington, D.C.: National Academy Press.

Office of Technology Assessment. 1984. Acid rain and transported air pollutants: Implications for public policy. Washington, D.C.

Olson, R.J., D.W. Johnson, and D.S. Shriner. 1982. Regional assessment of potential sensitivity of soils in the eastern United States to acid precipitation. Oak Ridge National Laboratory, Oak Ridge, TN.

Omernik, J.M. 1983. Total alkalinity of surface waters, 1982. U.S. Environmental Protection Agency.

U.S. Bureau of Census. 1980. Population by density. U.S. Department of Commerce.

U.S. - Canada Memorandum of Intent on Transboundary Air Pollution (US - Canada MOI). 1983. Final report of impact assessment. Work Group I.

U.S. Environmental Protection Agency (USEPA). 1979. Protecting visibility. An EPA report to Congress. Washington, D.C. EPA-450/5-79-008.

U.S. Environmental Protection Agency (USEPA). 1982. Air quality criteria for particulate matter and sulfur oxides (2). 600/8-82-029b.

U.S. Environmental Protection Agency (USEPA). 1983. The acidic deposition phenomenon and its effects: Critical assessment review papers(1). Public Review Draft. EPA-600/8-83-016A.

Wilson, R., S.D. Colome, J.D. Spengler, and D.G. Wilson. 1980. Health effects of fossil fuel burning: Assessment and mitigation. Cambridge, Ma: Ballinger Publishing Co.